BELLCOMM. INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 10042

SUBJECT: Handy Dandy Charts for Determining Operational Constraint Effects in Lunar Traverse Planning - Case 320

DATE: October 15, 1969

FROM: P. Benjamin

ABSTRACT

The effects of the limitations imposed by the life support system upon lunar surface traverse plans are presented in two charts. The charts are intended as aids in lunar traverse planning, and are useful in determining the operational tradeoffs available. They relate total traverse distance, PLSS consumables usage, total time in suit, number of scientific stations visited, and permissible radius of operations. A detailed description of their structure and instructions for their use are presented.

The charts are limited to consideration of only the life support operational constraints in traverse design. No consideration is given to such factors as communication, navigation, or geological objectives, and these areas must be considered separately. The charts are merely intended to be tools for use in traverse design and vehicles for tradeoff analyses. When used with caution and judgment, they can be effective in performing this task.

(NASA-CR-109061) HANDY DANDY CHARTS FOR DETERMINING OPERATIONAL CONSTRAINT EFFECTS IN LUNAR TRAVERSE PLANNING (Bellcomm, Inc.) 17 p

N79-71536

Unclas
00/04 11718

FF No.

(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

[redacted]

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 10042

SUBJECT: Handy Dandy Charts for Determining Operational Constraint Effects in Lunar Traverse Planning - Case 320

DATE: October 15, 1969

FROM: P. Benjamin

MEMORANDUM FOR FILE

INTRODUCTION

Multiple attempts over the past month have produced a series of charts which can be used to determine the effects of operational constraints and limitations on lunar surface EVA operations for traverse planning purposes. Either of the two charts presented here, representing the latest generation in development, performs this function. An earlier version of each was used in a previous exercise (1) to plan lunar surface traverses. Because of the large number of people whose ideas contributed to the structure and format of these charts in the process of their iterative development cycle, neither the credit nor the blame for their existence may be attributed to any one individual.

The significant parameters in these charts are total traverse distance, PLSS consumables limitations, total time in suit, number of scientific stations visited, and permissible radius of operations. Three modes of locomotion are considered --walking at 4 km/hr, riding the rover at 5 km/hr, and riding at 10 km/hr. The charts are developed for the A7L suit with the -7 PLSS and the SLSS. One chart is a nomograph and the other a graph. Although they differ slightly in the amount of information presented, either is equally valid for solving the operational constraints problem. They are both presented because various individuals have preferred one or the other format for working purposes.

ASSUMPTIONS

The metabolic rates shown in Table 1, which form the basis for the charts, reflect Apollo 11 and simulator experience, and are generally agreed upon throughout the program for planning purposes (2). They include the four major activities of lunar surface EVA. The increased values used for walking reflect the effects of payload, slope, wander, and surface characteristics.

The emergency walking value is lower than the nominal because it is assumed that the payload of 80 lbs will be discarded in an emergency walking return to the LM.

A total of 1 1/2 hours of overhead, as generally agreed upon and listed in Reference 2, is charged to the PLSS for each EVA, reducing its usable capacity from 6000 Btu to 4350 Btu. In an emergency return to the LM, 15 minutes of overhead for LM ingress and pressurization are charged to the SLSS, making its usable capacity 2125 Btu. The life support system capabilities are shown in Table 2.

Both a 5-hour and a 6-hour nominal suit time limit are shown, since a firm decision on the value to be used has yet to be made. No emergency suit time limit is used, although the 6-hour nominal suit limit should make emergency suit times of more than 7-hours very unlikely, and similarly a 5-hour nominal limit makes a 6-hour emergency time unlikely. A ground rule is that in the event of PLSS failure return to the LM be accomplished on the SLSS in the nominal mobility mode. The SLSS has a capability for a 15.2 km return to the LM on the rover at 5 km/hr and 30.4 km at 10 km/hr. These values are shown on the charts. Walking return at 4 km/hr permits a 6 km emergency distance on the SLSS. These values determine fixed maximum operational radii from the LM for each mobility mode. In the event of rover failure, a walking return using both PLSS and SLSS consumables is assumed. This represents a modification of a suggested PLSS consumables only return assumption. Since the SLSS provides a 6 km walking return distance, any traverse which goes more than 6 km from the LM must provide sufficient PLSS reserves to return walking to the 6 km radius point during the time that the rover is beyond this point. Similarily, if a PLSS consumables only return is assumed, PLSS reserves must be sufficient to return to the LM. The required PLSS reserves for walkback are integrated into the planning charts.

This analysis does not in any way deal with related traverse problems such as communications constraints or navigation requirements. Since the communications system is presently still undefined and navigation problems are a matter of debate, they have been eliminated from consideration. Clearly in a final planning stage, they must be integrated into the analysis. For the present, however, these charts may help to develop techniques and preliminary plans for tradeoff purposes.

CHART 1

Chart 1 (Figure 1) is in the form of a nomograph with five lines upon which the significant parameters are plotted.

Starting from the left, the first line indicates traverse distance. It has three scales, corresponding to walking at 4 km/hr and riding at 5 km/hr and 10 km/hr. The maximum radius allowed by the SLSS return is shown on this scale, although this is an emergency return, rather than nominal traverse, distance. The second line indicates the PLSS consumables used in a walking mission. In a nominal mission, no more than 4350 Btu's may be used, and this defines the PLSS limit shown. Line 3 indicates the number of hours which have been spent on the traverse. This is the number of hours of suit time minus the overhead. Thus with the 1 1/2 hour overhead, the 6-hour suit limit appears at 4 1/2 hours, and the 5-hour suit limit at 3 1/2 hours.

The fourth line plots PLSS consumables used (in Btu's expended) in a riding traverse up the right side and PLSS reserves for emergency walkback down the left side. As in walking missions, in a nominal riding mission no more than 4350 Btu's may be used, and this defines the PLSS limit shown. At this point, there are 6 km of walkback available in the SLSS, and for each additional km of walkback required 350 Btu's in the PLSS are reserved. If the rover is 10 km from the LM, only 2950 Btu's may have been used in the traverse to that point. As the rover returns toward the LM, these PLSS reserves are no longer required, so that at 8 km return distance a total of 3650 Btu's may have been used. If a PLSS consumables only walkback is assumed, 6 km must be subtracted from the values shown. Line 5 indicates the amount of time spent on science at the various stations. As an aid, the number of sites visited is also plotted for 10 minute, 15 minute, and 20 minute site times.

In order to use the nomograph, a point is chosen on the distance line corresponding to the distance traversed in the appropriate mobility mode. A second point is selected on line 5 corresponding to the amount of time to be spent on science. A line connecting these two points intersects lines 2, 3, and 4, giving the amount of time spent in the traverse (line 3) the cumulative metabolic load (line 2 for walking and line 4 for the rover), and the walkback distance capability. A detailed description of the use of the chart in the form of a sample traverse plan is given in Appendix A.

CHART 2

Chart 2 (Figure 2) presents most of the same information in graphical form. Although it does not show margins as clearly as

Chart 1, it is somewhat easier to use. Traverse distances are plotted along the abscissa in two scales. The upper scale applies to the rover at 5 km/hr or walking at 4 km/hr. The lower scale is used for the rover at 10 km/hr. The ordinate indicates the amount of time spent on science at the various stations. As an aid, the number of sites visited is also plotted for 10 minute, 15 minute, and 20 minute site times.

Total traverse distance and the number of sites visited in riding missions are determined by the -7 PLSS consumables limit line and the 6-hour suit limit line, or the 5-hour suit limit line. For walking missions, the dashed -7 PLSS consumables limit (walking) line determines the traverse distance and number of sites. Walkback capabilities over the 6 km provided by the SLSS are shown by the dashed lines parallel to the riding PLSS consumables limit. As in Chart 1 these values must be reduced by 6 km if a PLSS consumables only walkback is assumed. The walkback limits are bounded on the lower end by the time required to ride out to the walkback points, and on the higher end by the SLSS rideback limit, which defines the maximum radius of operations. Thus any point to the left of the rideout limit lines is within walkback capability, and any point to the right of the SLSS rideback line is beyond riding capability. Examples which describe the use of this chart are given in Appendix B.

CONCLUSION

The charts presented here may be used as tools to aid in the design of lunar surface traverses. They are only "slide rules" for determining the life support constraints of the traverses, and give no more consideration to communication or navigation restrictions than they do to the geological objectives. They must, therefore, be used with caution and judgment.

The validity of these charts is no greater than the validity of the assumptions which define them. Any change in the metabolic rates assumed (Table 1) invalidates both charts. Although Chart 1 can be easily modified to account for changes in ground rules, such as suit time limits or walkback constraints, Chart 2 must be redrawn for any such changes.

There is a strong restriction on these charts: They are aids, not answers. Given this caveat, it is hoped that they will prove useful in performing lunar surface traverse tradeoffs.

Peter Benjamin

2032-PB-tla P. Benjamin

Attachments

APPENDIX A

A SAMPLE TRAVERSE PLANNING EXERCISE WITH CHART 1:

As an example of the method used for traverse planning with Chart 1, consider the proposed science traverse shown in Figure 3A. The total distance covered by the traverse is 25 km, and 6 science stations are to be visited for 15 minutes each in the order indicated. A 10 km/hr rover is to be used, and a 6 hour suit limit is assumed.

Question 1: Is the traverse within suit time and PLSS consumables limits?

Step 1: Locate 25 km on the 10 km/hr rover scale on line 1 and 6 sites on the 15 min./site scale on line 5. The line drawn between them indicates a 4 hr traverse time (line 3) and a 3300 Btu metabolic load (line 4 for a rover traverse). There are large margins available.

Question 2: Are any SLSS limits violated?

Step 2: The 10 km/hr rover SLSS limit is 30.4 km as seen on line 1. Then the maximum return radius cannot exceed 30.4 km. Since the entire traverse is only 25 km, SLSS limits will pose no problems.

Question 3: Can the suit time limit and PLSS consumables margins be used to gain extra capability?

Step 3: Keeping the point at 25 km fixed draw a line through the 6 hr suit limit (which is the first limit reached) to show that 8 sites can be visited.

Step 4: Using the original 6 sites point on line 5 draw a line through the 6 hr suit limit to show that 30 km can be traversed. These two steps form a capability envelope.

Step 5: Increasing the number of science sites to 7, draw a line from 7 sites through the 6 hr suit limit to show that 27.75 km can be traversed.

In this case, it will be assumed that the greatest scientific yield can be obtained by reaching a single additional site at a slightly greater distance. The other alternatives would be to increase the traverse length a great deal with the same number of sites, or to increase the number of sites while keeping the traverse length constant. Accordingly, the traverse is redesigned to pick up an additional scientific station as shown in Figure 3B. The traverse is now 27 km long and visits 7 science stations.

Question 4: Are any walkback constraints violated?

Step 6: Start by checking the site farthest from the LM, site 5. Emergency return from site 5 would be accomplished along the planned traverse route. Site 5 is 15 km into the traverse, with a 12 km walkback return. Draw a line from 15 km on the distance scale to 5 sites on the science station scale. This intercepts the walkback scale at 11.6 km, indicating that the walkback requirement is violated.

Question 5: What modifications to the traverse are required to remove the walkback violation?

Step 7: If the route is traversed in the opposite direction (clockwise instead of counterclockwise) site 5 is only the third site, only 12 km into the traverse with the same 12 km walkback requirement. Draw a line between 12 km on line 1 and 3 sites on line 5. This shows a 13.7 km walkback capability, well beyond the requirement. Therefore, no change in the traverse is necessary except that a clockwise direction should be used.

Question 6: Are there any other possible walkback violations?

Step 8: Site 4 is the fourth station, 14.5 km into the traverse, going clockwise. The specially planned emergency return path (dashed line) is 10 km in length. A line between 14.5 km on the distance scale and 4 sites on the science station scale intercepts 12.4 km on the walkback scale, indicating a good margin. To be thorough, site 3 should also be checked. It is also within walkback range.

The farthest site is not always the most constraining in terms of the walkback requirement. This is why sites 4 and 3 would be checked. If these were far enough from the LM, the additional consumables spent at that distance could violate the walkback limit even though a farther out site earlier in the traverse did not.

APPENDIX B

EXAMPLES OF THE USE OF CHART 2

Since the technique used in traverse planning is presented in detail in Appendix A for Chart 1, it will not be repeated here. The examples here will locate the same points as were found in Appendix A, and reference is made to the appropriate values as used in Appendix A. A careful reading of Appendix A is recommended before traverse planning with either chart is attempted.

1. To determine suit time and PLSS consumables limits for the nominal traverse (as in step 1 of Appendix A): Locate the traverse distance, 25 km, on the 10 km/hr rover scale on the abscissa. Locate 6 sites on the ordinate. Draw a vertical line from the traverse distance and a horizontal line from the number of sites to their point of intersection. Since this point is within the bounds determined by the PLSS consumables and assumed 6 hour suit time limit lines, there are margins available.

2. To determine the capability available from the margins (steps 3, 4, and 5 of Appendix A): Extend the horizontal line from 6 sites to the suit limit line and draw a vertical line from the intersection with the 6 hr suit limit to intercept the abscissa at 30 km. Extend the vertical line from 25 km to the 6 hr suit limit and draw a horizontal line from this intersection to the ordinate at 8 sites. Note that the envelope so formed includes the 7 site, 27.75 km option chosen.

3. To determine SLSS limit violations: Note that the maximum radius indicated on Chart 2 is 30.4 km, greater than the entire traverse length.

4. To determine emergency walkback capability (step 6 in Appendix A): Site 5 is 15 km into the traverse with a 12 km return path along the planned traverse route. Enter 15 km on the abscissa and 5 sites on the ordinate. Their intersection defines the walkback capability read on the dashed walkback lines. The 11.6 km indicated is insufficient.

TABLE 1

ASSUMED METABOLIC EXPENDITURES

ACTIVITY	METABOLIC RATE (BTU/HR)
WALKING (4 KM/HR)	1000
RIDING	700
SCIENCE	1100
OVERHEAD	1100

WALKING VALUES USED AS MODIFIED BY PAYLOAD SLOPE, WANDER FACTOR, ETC:

NOMINAL	1625 BTU/HR
EMERGENCY (NO LOAD)	1400 BTU/HR

TABLE 2

LIFE SUPPORT SYSTEM CAPABILITIES

-7 PLSS CAPACITY	6000 Btu
1 1/2 HOURS OVERHEAD	-1650 Btu
AVAILABLE FOR TRAVERSE	4350 Btu
SLSS CAPACITY	2400 Btu*
15 MIN. OVERHEAD	- 275 Btu
AVAILABLE FOR RETURN	2125 Btu

*excludes 800 Btu reserved for LM/CM soft dock transfer

References

1. "Evaluation of Mobility Modes on Lunar Exploration Traverses: Marius Hills, Copernicus Peaks and Hadley-Apennines Missions," Draft, P. Benjamin, T. A. Bottomley, J. W. Head, and M. T. Yates.

2. "Definition of Energy Costs for Lunar Surface EVA," Bellcomm Memorandum for File B69 09027, T. A. Bottomley, September 8, 1969.

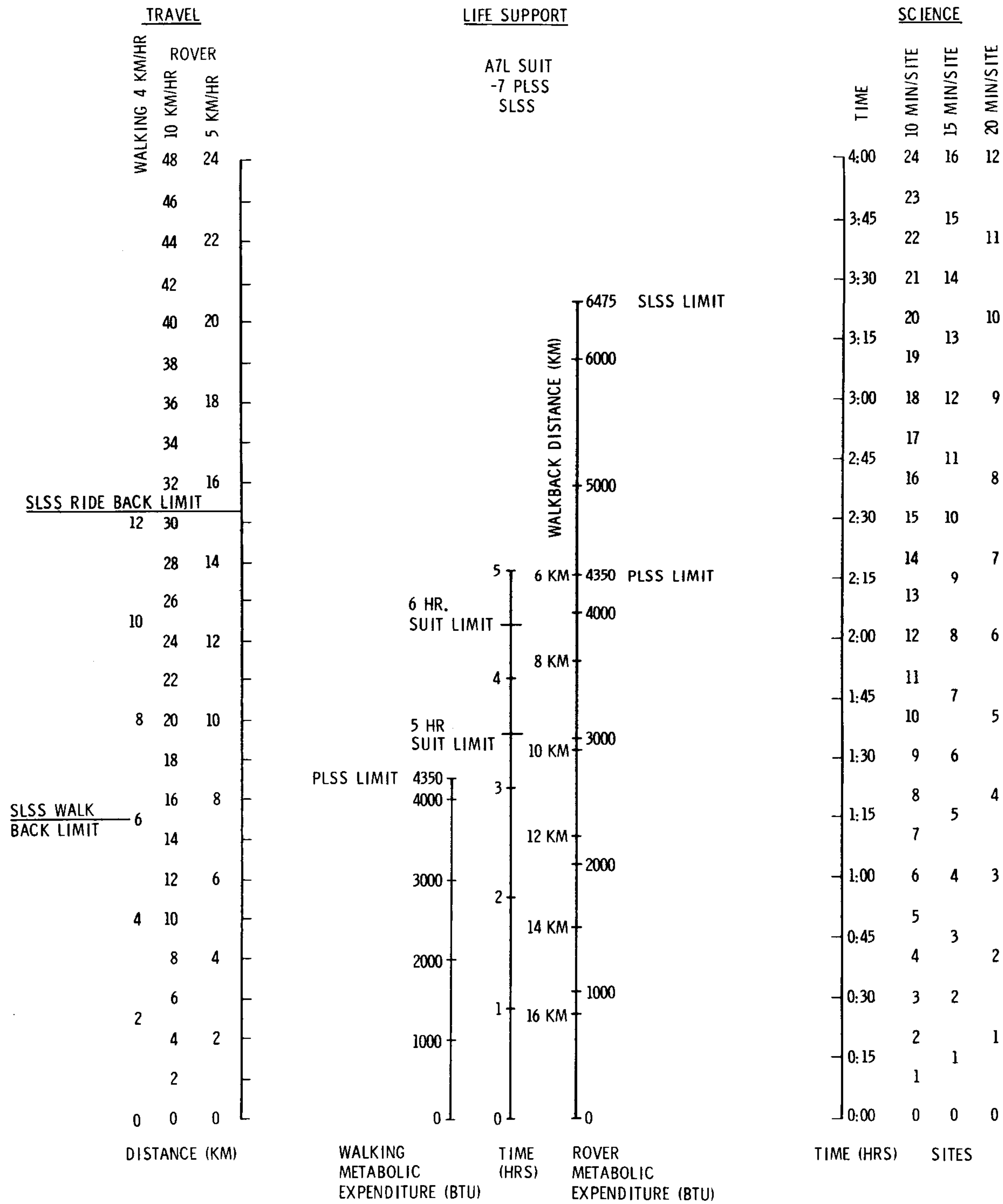

FIGURE 1 - TRAVERSE PLANNING CHART 1

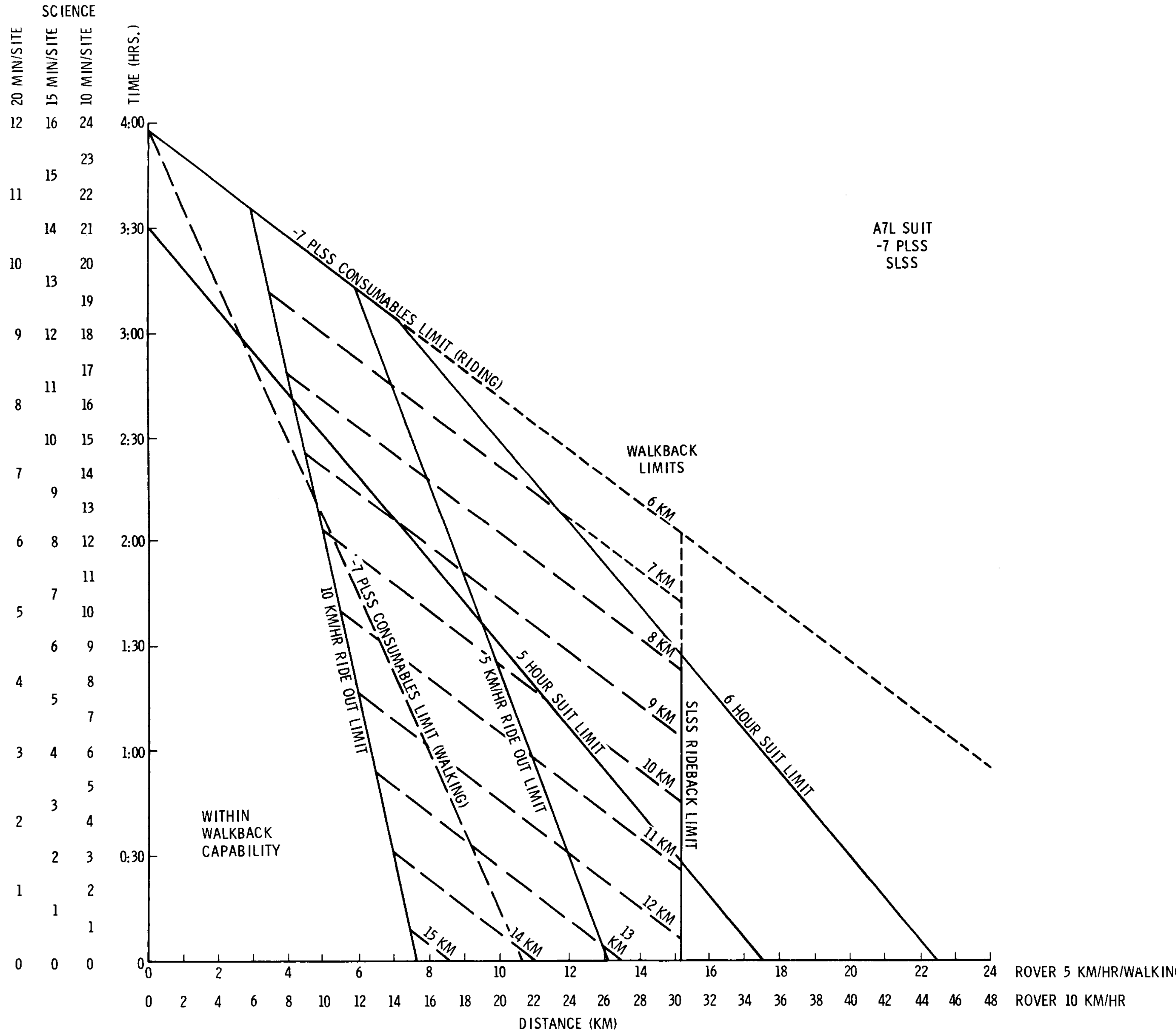

FIGURE 2 - TRAVERSE PLANNING CHART 2

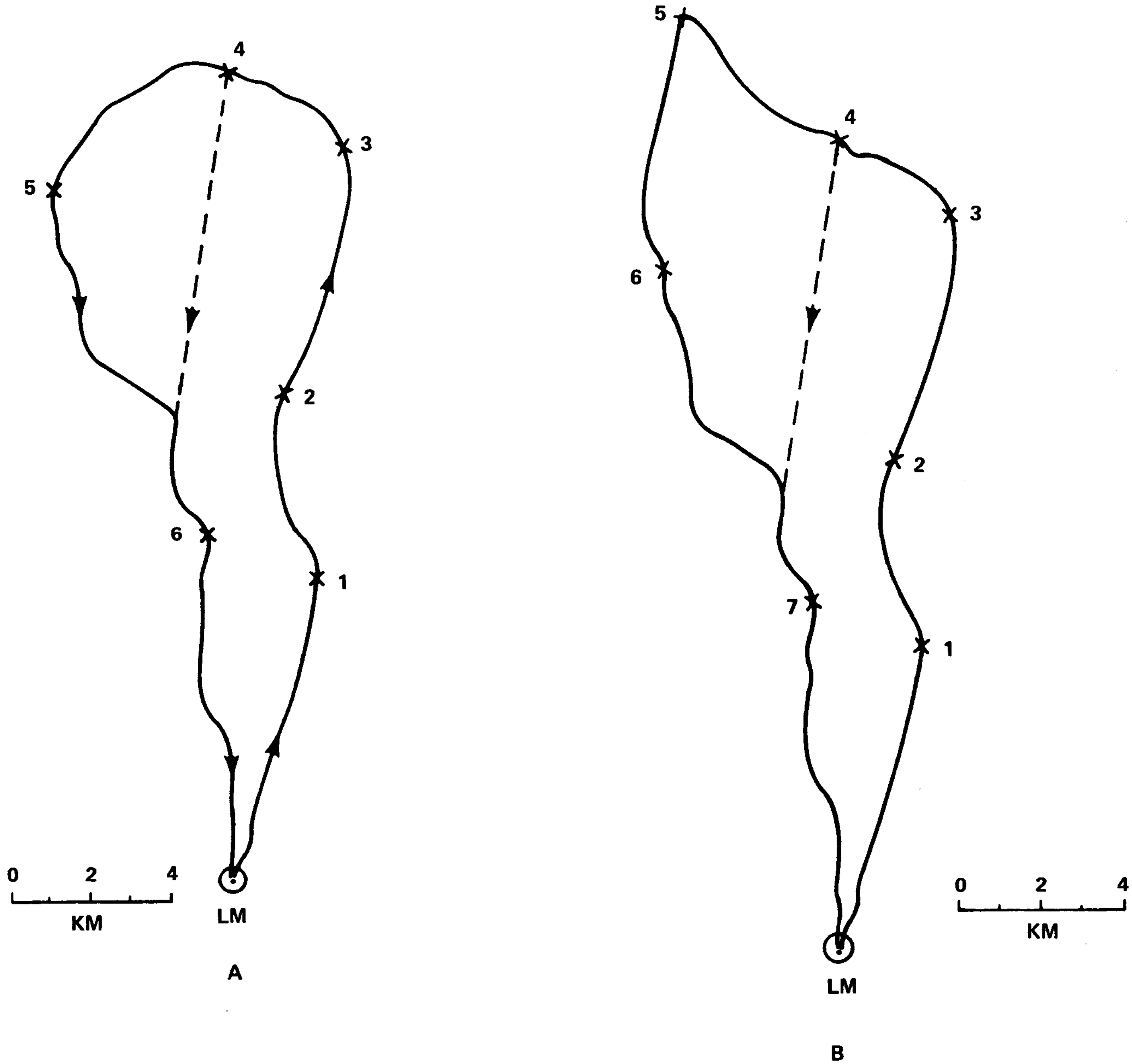

FIGURE 3 - SAMPLE TRAVERSES

BELLCOMM, INC.

Subject: Handy Dandy Charts for Determining Operational Constraint Effects in Lunar Traverse Planning - Case 320

From: P. Benjamin

Distribution List

NASA Headquarters

R. J. Allenby/MAL
R. O. Aller/MAO
D. A. Beattie/MAL
M. Behun/MAT
F. B. Benjamin/MM
H. S. Brownstein/MM
G. P. Chandler/MAO
G. F. Esenwein/MAL
C. C. Gay, Jr./MAT
R. Hessburg/MM
J. K. Holcomb/MAO
J. W. Humphreys/MM
T. A. Keegan/MA-2
C. H. King/MAT
E. W. Land/MAO
C. M. Lee/MA
M. Malloy/MAL
B. Milwitzky/MAL
R. A. Petrone/MA
A. F. Phillips, Jr./MAT
H. W. Randel/MM
L. R. Scherer/MAL
R. B. Sheridan/MAO
J. D. Stevenson/MO
W. E. Stoney/MA
R. Toms/MAL
S. P. Vinograd/MM
C. Wertz/MAL
R. L. Wetherington/MAT

MSC

L. E. Bell/EC6
C. A. Berry/DA
J. Bilodeau/CF2
R. L. Bond/PD8
A. J. Calio/TA
A. B. Carraway/TD3
A. D. Catterson/DA

MSC (Cont'd)

J. D. Hodge/HA
C. C. Kraft/FA
H. A. Huehnel/CF32
J. P. Loftus/HA
J. A. McDivitt/PA
A. J. Meyer/HA
W. J. North/CF
J. W. O'Neill/CF34
D. B. Pendley/FC
C. H. Perrine/PO
E. B. Pippert/CF34
R. G. Rose/FA
J. H. Sasser/TH3
H. H. Schmitt/CB
D. C. Schultz/CF25
J. R. Sevier/PD
D. K. Slayton/CA
R. E. Smylie/EC
H. W. Tindall/FM
L. C. Wade/TH3
C. H. Woodling/CF3
J. G. Zarcaro/PD
R. G. Zedekar/CF32

MSFC

J. P. Belew/R-AS-ML
J. S. Hamilton/R-TEST-B
S. F. Morea/1-E-MGR
W. R. Perry/PM-SAT-LRV
M. J. Vaccaro/R-P&VE-VA
O. H. Vaughn, Jr./R-AEROY

TRW Systems

D. T. Appleton
J. P. Herbaugh
L. E. Wood

Subject: Handy Dandy Charts for Determining Operational Constraint Effects in Lunar Traverse Planning - Case 320

From: P. Benjamin

Distribution List (Cont'd)

USGS/Flagstaff

A. H. Chidster
D. P. Elston
T. N. V. Karlstrom
H. Masursky
R. Regan
G. A. Swann
G. E. Ulrich

USGS/Menlo Park

J. F. McCauley
N. J. Trask
D. E. Wilhelms

LaRC

G. Beasley
R. Stone

Bellcomm, Inc.

D. R. Anselmo
A. P. Boysen
J. O. Cappellari
D. A. Corey
B. A. Gropper
D. R. Hagner
W. G. Heffron
J. J. Hibbert
T. B. Hoekstra
B. T. Howard
D. B. James
A. N. Kontaratos
J. Z. Menard
V. S. Mummert
P. E. Reynolds
I. M. Ross
L. D. Sortland
R. V. Sperry

Bellcomm, Inc. (Cont'd)

W. B. Thompson
J. W. Timko
R. L. Wagner
M. P. Wilson
Central Files
Department 1024 File
Department 2015
Department 2032
Library